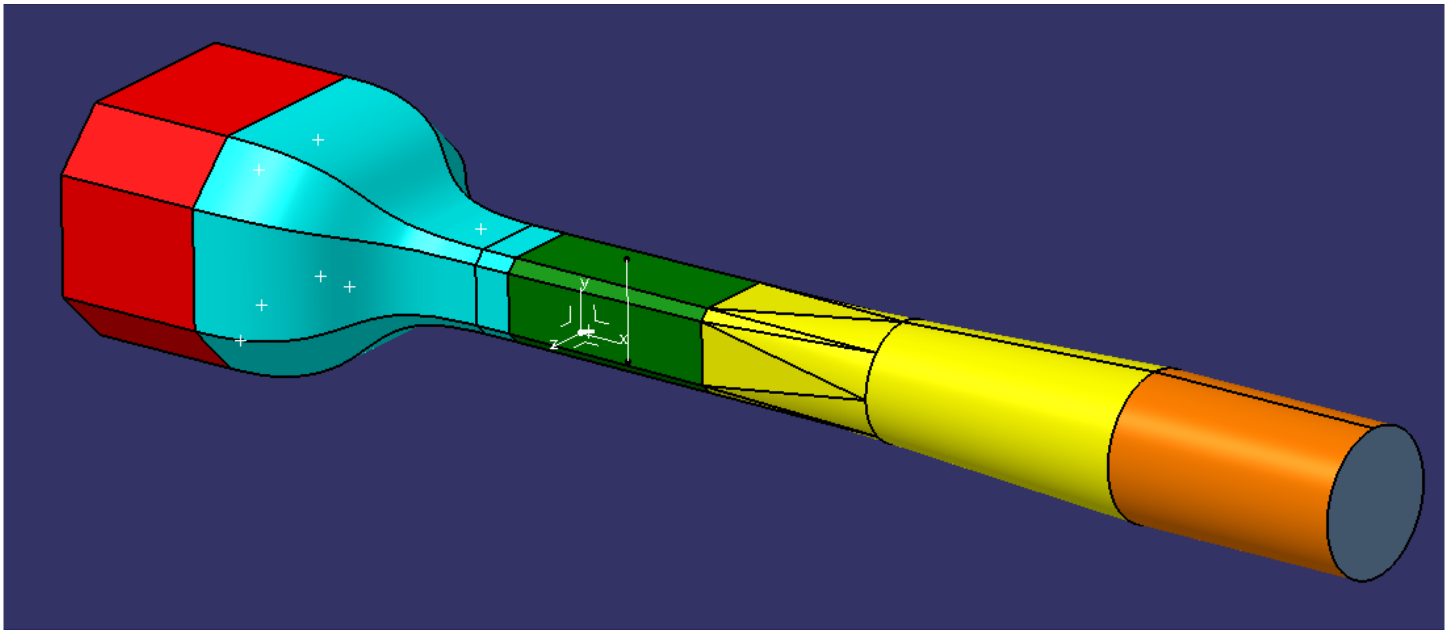
4th AIAA CFD High Lift Prediction Workshop

QinetiQ 5m Wind Tunnel Modeling

Tunnel Geometry

Geometry representative of the QinetiQ 5m Wind Tunnel (5mWT), including the contraction and diffuser sections are contained in the file ***q5m_forHLPW4.igs***. It is a collection of surfaces, points and lines as shown below. The surfaces consist of 7 distinct zones. The Inlet (not shown), Inlet Extension (red), Contraction (blue), Test Section (green), Diffuser (yellow), Diffuser Extension (Orange), and the Outlet (Grey).



Tunnel geometry is provided such that the full scale geometry of the CRM-HL provided for HLPW4 will be oriented and scaled appropriately. In order to obtain the desired angle of attack, the tunnel and all associated probes should be rotated around the provided centerline, 'TurntableCL', with airplane nose up being a positive Angle of Attack.

This approach means that the tunnel geometry is 10x larger than in reality to account for the 10% model scale. This allows for consistent post processing between free air and in-tunnel runs, but requires adjustments to the fluid properties in order to match Reynolds Numbers. As with the free air cases, adjusting the Kinematic Viscosity is the preferred approach. An alternate approach would be to scale the entire geometry set by 0.10, and running with real air specifications.

Additionally, a standoff is required in order to join the airplane to the tunnel walls. This standoff is provided in ***standoff_simple.igs***, and should be joined to the CRM-HL Fuselage, and intersected with the wind tunnel floor, in order to complete a water-tight surface.

The two extensions provided are recommended for computational studies. At the inlet, several of the probe locations lie quite close to the inlet boundary. Here, moving the inlet boundary further upstream is a logical choice. In the diffuser, CFD can have difficulties should separation occur near the outflow boundary. A common approach is to add a constant area extension on the back of the diffuser (See AIAA-2017-4126, AIAA-2019-0080). An alternate approach could be to shorten the diffuser such that outflow occurs prior to any separation.

Both extension pieces can be treated as inviscid walls, while the contraction, test section, and diffuser are treated viscously.

Boundary Condition Strategy

Specification of the Mach number, temperature and Reynolds number for the CFD simulations in the wind tunnel are the same as those provided for the free air cases.

Specific strategies for performing CFD simulations when modeling the wind tunnel installation for the juncture flow experiment is applicable here: https://turbmodels.larc.nasa.gov/Other_exp_Data/JunctureFlow/rumsey-strategies-to-run-in-tunnel-3.pdf

Inflow

The Inflow boundary should specify Total Pressure and Total Temperature. Inviscid Thermodynamic Relations are used to define the inflow boundary values, as in AIAA-2017-4126:

$$\frac{p_{t,\mathrm{inflow}}}{p_{\mathrm{min}}} = \left(1 + \frac{\gamma - 1}{2}\,M_{\mathrm{min}}^2\right)^{(\gamma/\gamma - 1)}, \quad \frac{T_{t,\mathrm{inflow}}}{T_{\mathrm{min}}} = \left(1 + \frac{\gamma - 1}{2}\,M_{\mathrm{min}}^2\right)$$

In the equations above, the minimum values occur in the test section, and are the reference quantities P_{ref}, T_{ref}, and M_{ref}.

Outflow

At the outflow plane, back pressure should be adjusted either iteratively by hand, or automatically, to achieve the specified Mach and Reynolds number. The achieved values are measured using the calibration information below.

5mWT Measurement Calibrations and Flow Condition Determination

The 5mWT uses total pressure (PT), total temperature (TT) and the static pressure drop (difference) between two pressure tap locations in the contraction (denoted "Max-Noz", see below) to define the conditions in the test section. A tunnel speed calibration is used to determine the relationship between the dynamic pressure (q) at the center of the test section and the static pressure drop. In normal operation, tunnel control is based on commanded values for Mach number (M) and Reynolds number.

Total Temperature

Total temperature is measured at four probe locations upstream of the contraction. These are labeled '*TempProbe**'. An average value is determined, and used to define the average total temperature achieved.

Total Pressure

'PTprobeTip' is the tunnel probe that measures the achieved total pressure.

Static Pressures

Two static probe locations are provided. Maximum Static Pressure (Max) is defined as the surface point labeled '*S3Static*', while Nozzle Static Pressure (Noz) is the surface point labeled '*S1Static*'.

Tunnel Calibrations

Using pressure data from the static probes, a value for (Max-Noz)/PT can be calculated directly. For a given tunnel pressure, QinetiQ provides a table of q/PT vs (Max-Noz)/PT, valid for the pressure range of the test cases. Linear interpolation can be used to determine a q/PT value.

q/PT	***(Max-Noz)/PT***
0.0190	0.0169265
0.0425	0.0380820
0.1001	0.0904813

The relationship between q/PT and the test section Mach number (M) is defined as:

$$q/PT = 0.7M^2 \, (1 + 0.2M^2)^{-3.5}$$

Once M is computed, the inviscid thermodynamic relations can again be used to calculate the achieved P_{ref}, T_{ref}, and Reynolds number.

Boundary Layer Rake

A set of 19 pressure probes are provided to represent the boundary layer rake. These are labeled '*BLRake01'* through '*BLRake19'.* Data from these can be used to compare against the achieved boundary layer profile.